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Random Beamforming OFDMA for Future Generation Cellular Communication Systems

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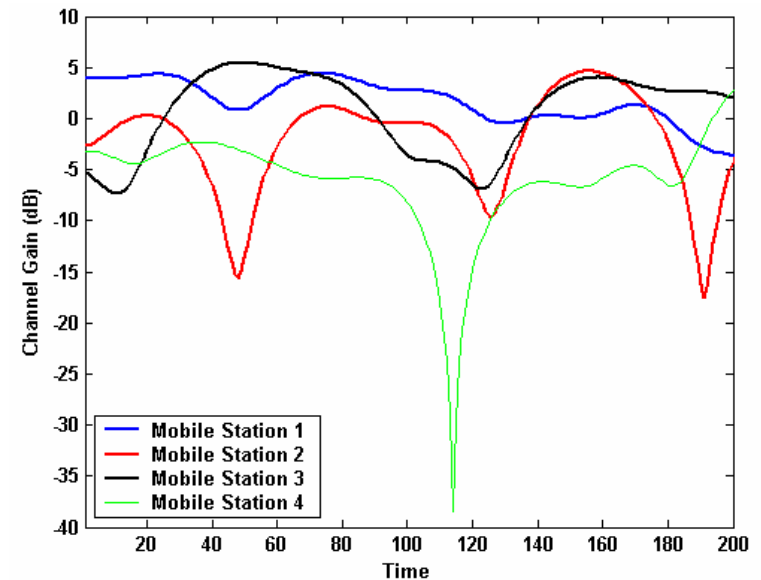
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Outline

- Introduction
- PHY Models of Random and Layered Random Beamforming OFDMA Systems
- Numerical and Simulation Results
- Conclusions and Future Work

Multi-user Diversity

- Multi-user Diversity: In a multi-user environment, it is likely to be at least one mobile station whose channel is near its peak at one time/frequency provided different mobile stations have independent fading channels.



- Exploiting the multi-user diversity by prioritizing the mobile stations with best current channel conditions can improve the overall system performance.

Opportunistic Beamforming

- Traditional eigenbeamforming (SVD)
 - achieve optimal performance
 - full channel state information (CSI) is required
 - feedback grow as a product of N_t and N_r
- Opportunistic beamforming (OB)
 - a random beamforming pattern
 - exploit multi-user diversity in combination with transmit beamforming to attain the coherent beamforming capacity
 - Only requires the feedback of SNR.

Random Beamforming (RB) and Layered Random Beamforming (LRB)

- Random beamforming (RB)
 - a combination of the OB and SVD
 - achieve spatial multiplexing gain and spatial multi-user diversity gain
 - feedback ESNR based rate.
- Layered random beamforming (LRB)
 - allow different spatial layers of the MIMO channels to be allocated to different mobile stations to achieve a further layer spatial multi-user diversity gain
 - MMSE based receiver, feedback ESINR based rate

Traditional and Random Beamforming

$$SVD(H) = U \times D \times V^H$$

U and V are unitary matrices, D is the singular value matrix

Traditional Eigenbeam-forming:

$$Y = HX + N = UDV^H X + N$$

$$X' = VX$$

$$U^H Y = U^H UDV^H X' + U^H N = DX + U^H N$$

Random Beamforming:

$$X' = V_R X \quad \text{Randomly Pre-coding Unitary Matrix } V_R$$

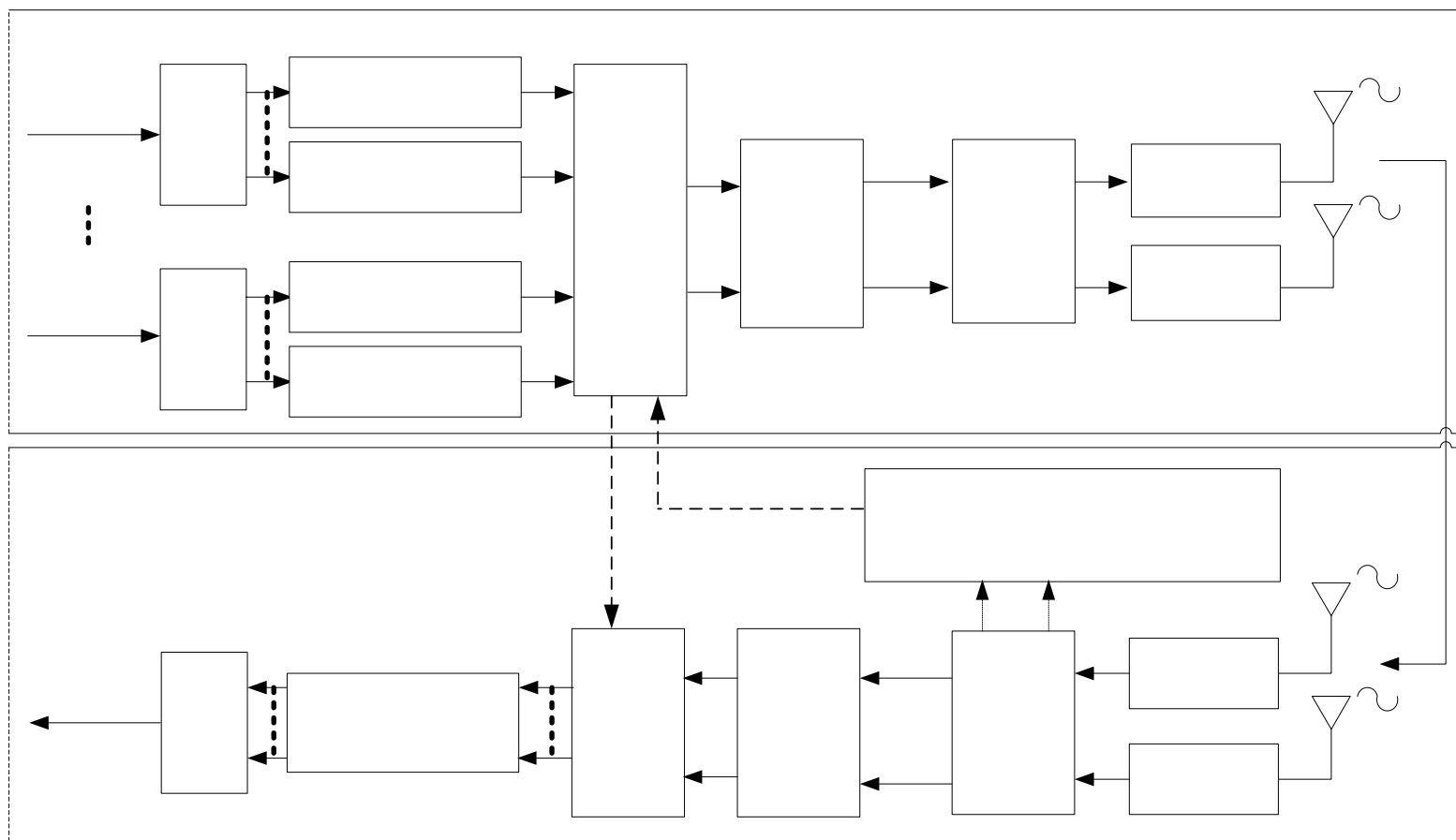
Combine RB and LRB with OFDMA

- OFDMA system is one of the most promising PHY and multiple access candidates for future communication systems. (WiMAX standard (802.16), Long Term Evolution (LTE) of 3GPP).
- RB and LRB-OFDMA achieves a further spectral multi-user diversity gain compared to the case of a single-carrier system.
- In an OFDMA system, feedback from every sub-carrier can be reduced by calculating the average data rate across all subcarriers in each cluster (a group of sub-carriers adjacent in frequency) and sending it to the BS through the feedback channel.
- Greedy scheduling algorithm is employed to select the best MS:

$$\text{RB-OFDMA: } r_{k^*,c}^* = \max \{r_{1,c}, r_{2,c}, \dots, r_{k,c}, \dots\}$$

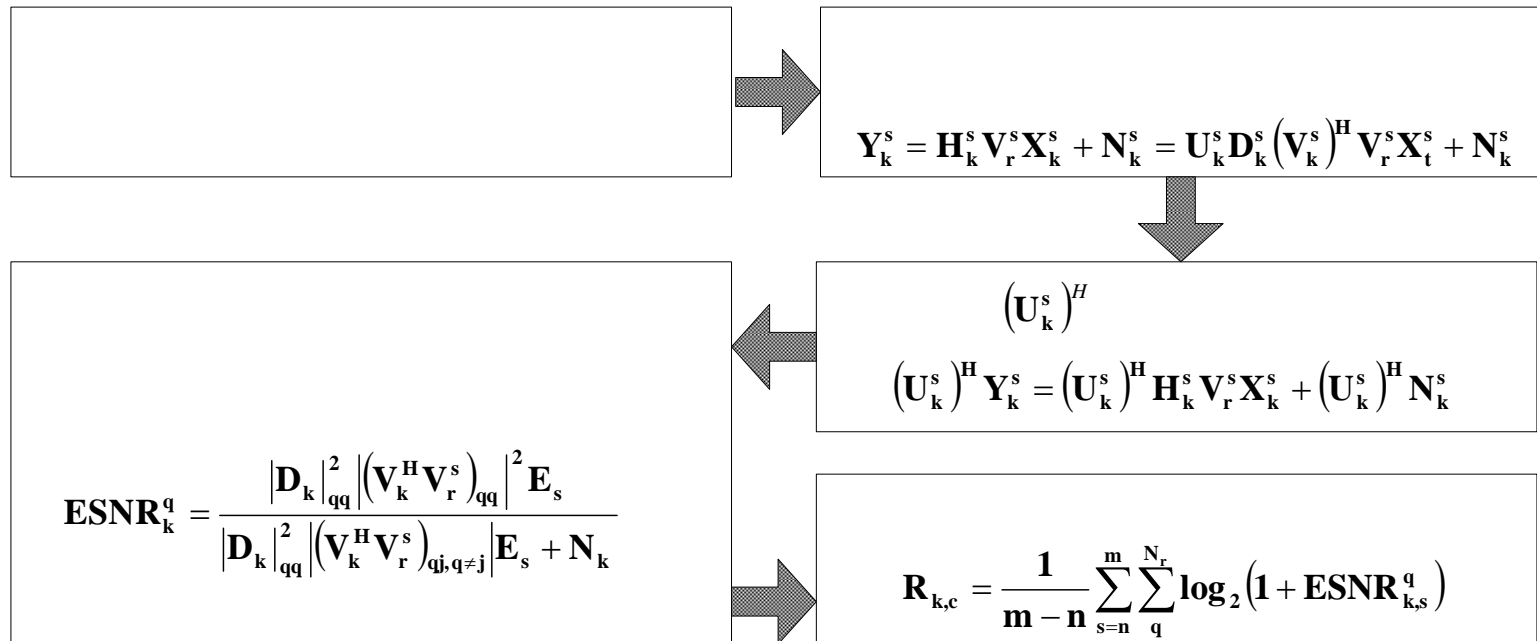
$$\text{LRB-OFDMA: } r_{k^*,c}^q = \max \{r_{1,c}^q, r_{2,c}^q, \dots, r_{k,c}^q, \dots\}$$

RB-OFDM/A and LRB-OFDM/A



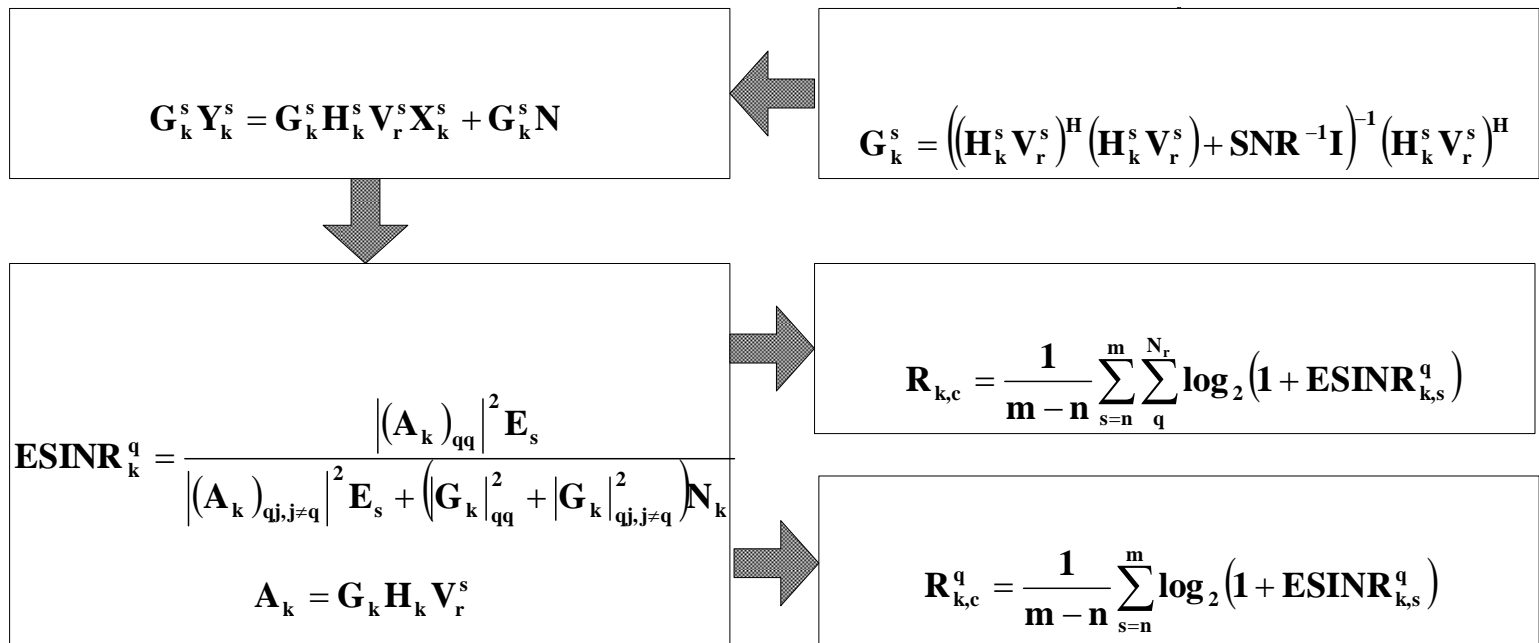
Transmitter at
Base Station

ESNR Based RB-OFDM/A



ESNR considers the eigenvalues of the MIMO channels and the mismatch between the random precoding matrix and the unitary matrix of the actual MIMO channels.

ESINR Based RB-OFDMA and LRB-OFDMA



ESINR indicates the eigenvalues of the MIMO channels and the mismatch between the random precoding matrix and the unitary matrix of the actual MIMO channels and it also considers the self-interference caused by the other spatial layers.

Simulation Parameters and Channel Model

System
Parameters

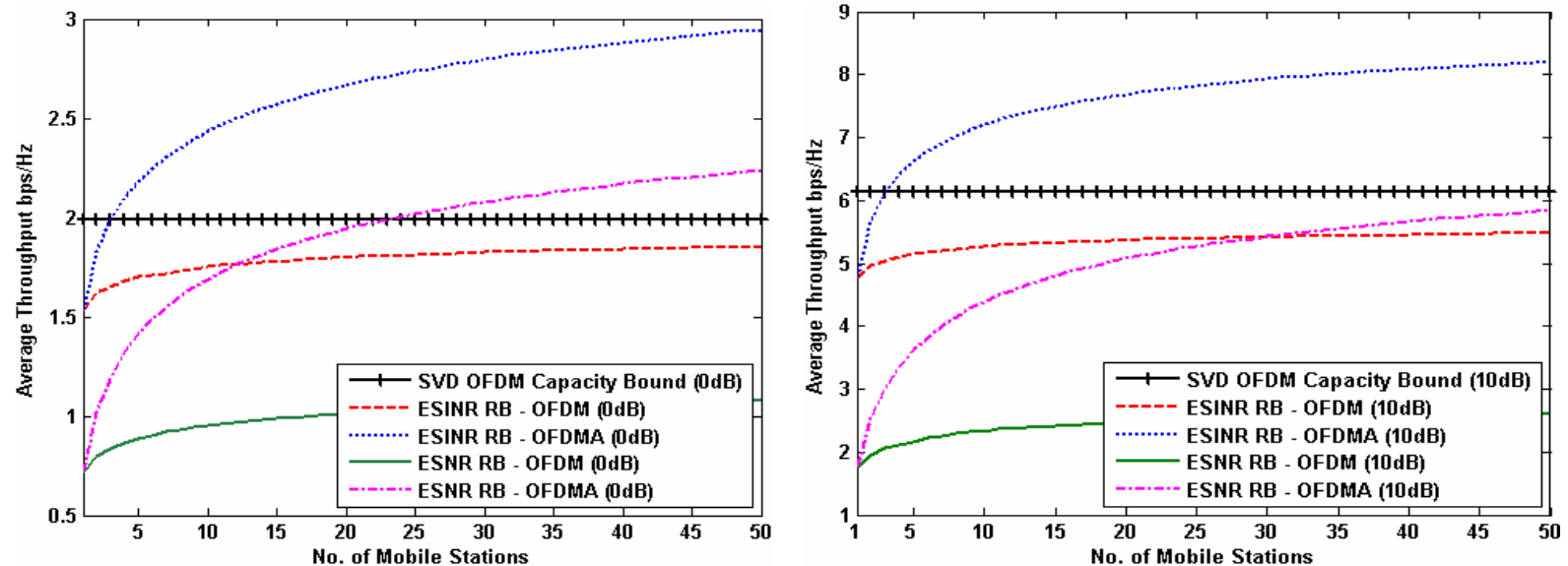
Operating Frequency	5 GHz
Bandwidth	100 MHz
FFT Size	1024
Useful Sub-carriers	768
Guard Interval Length	176
Sub-carrier Spacing	97.656 KHz
Useful Symbol Duration	10.24 μ s
Total Symbol Duration	12.00 μ s
Inner Channel Coding	Punctured 1/2 rate convolutional code, constraint length 7, $\{133,171\}_{octal}$
PHY Mode	Modulation: 64QAM, Coding Rate 3/4

Channel Model

	τ_{rms}	τ_{max}	τ_{rms}		

Numerical Analysis - ESNR vs. ESINR

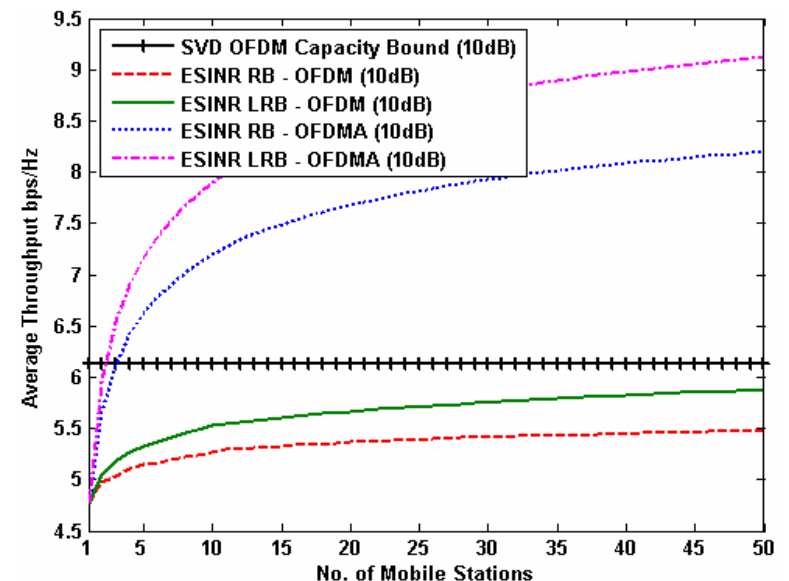
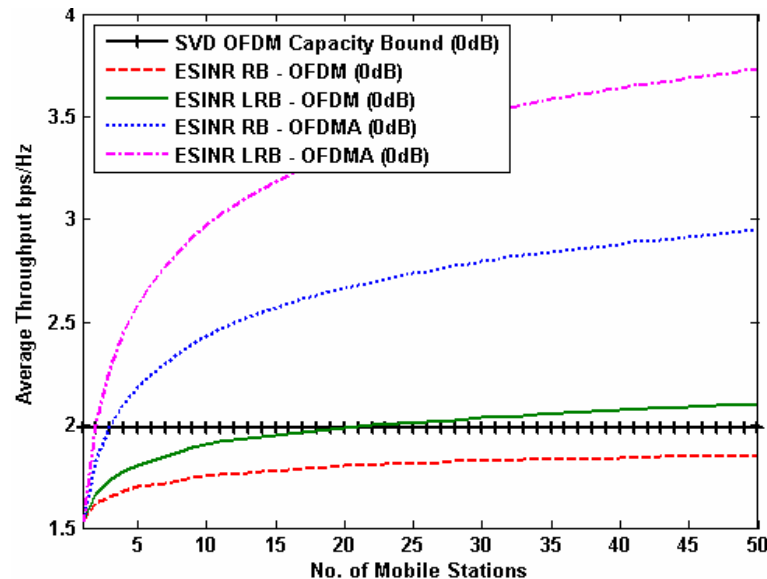
Average Numerical Throughput Performance of ESNR and ESINR based RB-OFDM systems in channel E as the Number of MSs Changes at SNR = 0dB and 10dB



Compared to ESNR, ESINR metric takes self-interference minimization into account and shows better numerical data rate.

Numerical Analysis - ESINR RB vs. LRB

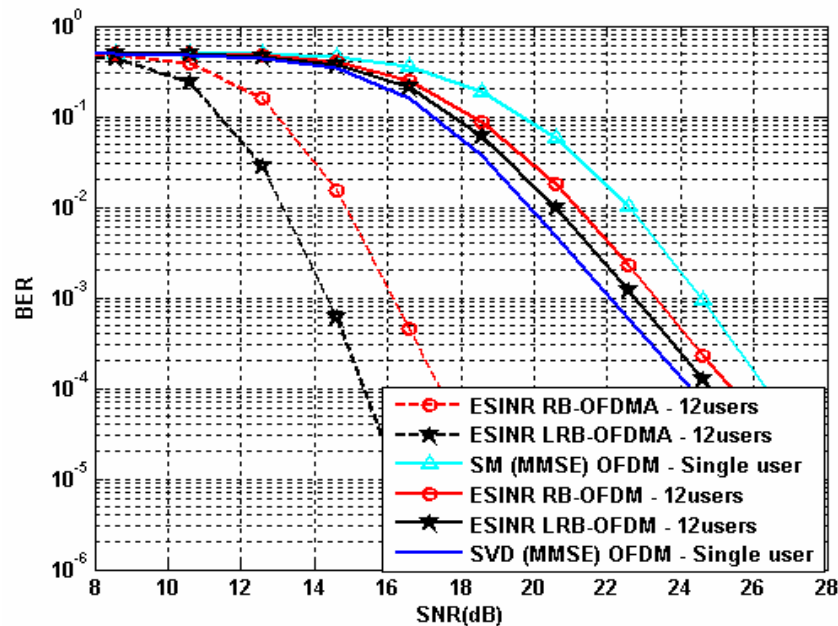
Average Numerical Throughput Performance of ESINR RB-OFDM, RB-OFDMA, LRB-OFDM, LRB-OFDMA systems in channel E as the Number of MSs Changes at SNR = 0dB and 10dB



- RB-OFDMA significantly outperforms RB-OFDM shows that the spectral multi-user diversity gain plays an important role.
- LRB shows an additional layer spatial multi-user diversity gain.

Simulation Performance - Various MIMO Schemes

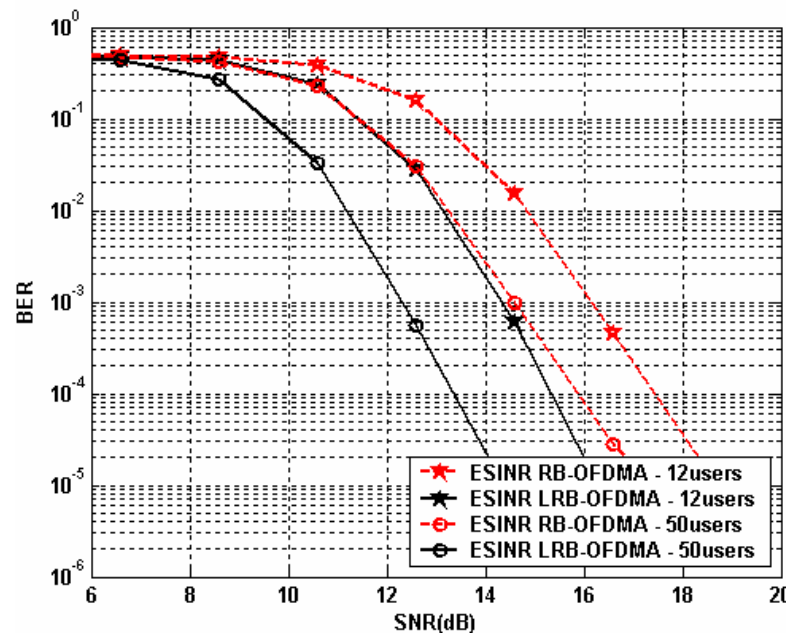
BER of RB-OFDM/A, LRB-OFDM, LRB-OFDMA and SVD-OFDM in Channel E (12 MSs in the Environment)



- LRB-OFDMA performs best due to its ability to effectively exploit both spectral and layer multi-user diversity gain.

Simulation Performance - Larger Number of Mobile Stations in the Environment

BER Performances of 12-MSs and 50-MSs ESINR RB/LRB-OFDMA in Mode 6 in Channel E



- More MSs --- Higher spatial multi-user diversity gain.
- Provided a large number of MSs in the environment, the effect of precoding matrix mismatch becomes very low.

Feedback Comparison

MIMO $N = \min(N_T, N_R)$	System	No. of Subcarrier	Cluster Size	Feedback Order	MSs in the environment	Supported MSs Simultaneously	Feedback From Every MS k
SM	OFDM	S	S	1	1	1	0
SVD	Single Carrier	1	1	1	K	1	$N_T N_R$
SVD	OFDM	S	S	1	K	1	$N_T N_R S$
SVD	OFDMA	S	C	1	K	K	$N_T N_R S$
RB	Single Carrier	1	1	1	K	1	1
RB	OFDM	S	S	1	K	1	1
RB	OFDMA	S	C	1	K	K	S
RB (RF)	OFDMA	S	C	1	K	K	(S/C)
LRB	Single Carrier	1	1	N	K	1	N
LRB	OFDM	S	S	N	K	1	N
LRB	OFDMA	S	C	N	K	K	NS
LRB (RF)	OFDMA	S	C	N	K	K	$N(S/C)$

Conclusions and Future Work

- Layered random beamforming MIMO-OFDMA achieves:
 - * spatial multiplexing gain * spatial multi-user diversity gain
 - * layer spatial multi-user diversity gain * spectral multi-user diversity in frequency selective channels.
- LRB only require achievable data rate feedback based on ESINR from every spatial layer. Feedback can be generated on a cluster basis (a group of sub-carriers adjacent in frequency) to reduce feedback for an LRB-OFDMA system.
- Future work
 - * fair scheduling algorithms * impact of feedback reduction on performance * simulation based on realistic outdoor channel

- Thank you for listening.
- Any questions, please?

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